OPEN-FILE REPORT 98-15

SEISMIC HAZARD EVALUATION OF THE EL MONTE 7.5-MINUTE QUADRANGLE, LOS ANGELES COUNTY, CALIFORNIA

1998

DEPARTMENT OF CONSERVATION
Division of Mines and Geology

THE RESOURCES AGENCY	STATE OF CALIFORNIA	DEPARTMENT OF CONSERVATION
MARY D. NICHOLS	GRAY DAVIS	STEVE C. ARTHUR
SECRETARY FOR RESOURCES	*GOVERNOR*	*ACTING DIRECTOR*

DIVISION OF MINES AND GEOLOGY
JAMES F. DAVIS, *STATE GEOLOGIST*

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PREFACE

With the increasing public concern about the potential for destructive earthquakes in northern and southern California, the State Legislature passed the Seismic Hazards Mapping Act in 1990. The purpose of the Act is to protect the public from the effects of strong ground shaking, liquefaction, landslides or other ground failure, and other hazards caused by earthquakes. The program and actions mandated by the Seismic Hazards Mapping Act closely resemble those of the Alquist-Priolo Earthquake Fault Zoning Act (which addresses only surface fault-rupture hazards) and are outlined below:

1. **The State Geologist** is required to delineate the various "seismic hazard zones."

2. **Cities and Counties**, or other local permitting authorities, must regulate certain development "projects" within the zones. They must withhold the development permits for a site within a zone until the geologic and soil conditions of the project site are investigated and appropriate mitigation measures, if any, are incorporated into development plans.

3. **The State Mining and Geology Board (SMGB)** provides additional regulations, policies, and criteria to guide cities and counties in their implementation of the law. The SMGB also provides criteria for preparation of the Seismic Hazard Zone Maps (Web site http://www.consrv.ca.gov/dmg/shezp/zoneguid/) and for evaluating and mitigating seismic hazards.

4. **Sellers (and their agents)** of real property within a mapped hazard zone must disclose at the time of sale that the property lies within such a zone.

As stated above, the Act directs the State Geologist, through the Division of Mines and Geology (DMG) to delineate seismic hazard zones. Delineation of seismic hazard zones is conducted under criteria established by the Seismic Hazards Mapping Act Advisory Committee and its Working Groups and adopted by the California SMGB.

The Official Seismic Hazard Zone Maps, released by DMG, which depict zones of required investigation for liquefaction and/or earthquake-induced landslides, are available from:

BPS Reprographic Services
149 Second Street
San Francisco, California 94105
(415) 512-6550

Seismic Hazard Evaluation Reports, released as Open-File Reports (OFR), summarize the development of the hazard zone map for each area and contain background documentation for use by site investigators and local government reviewers. These Open-File Reports are available for reference at DMG offices in Sacramento, San Francisco, and Los Angeles. Copies of the reports may be purchased at the Sacramento, Los Angeles, and San Francisco offices. In addition, the Sacramento office offers prepaid mail order sales for all DMG OFRs. **NOTE: The Open-File Reports are not available through BPS Reprographic Services.**

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(213) 239-0878

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Seismic Hazard Evaluation Reports and additional information on seismic hazard zone mapping in California are available on the Division of Mines and Geology's Internet homepage: http://www.consrv.ca.gov/dmg/shezp/

INTRODUCTION

The Seismic Hazards Mapping Act (the Act) of 1990 (Public Resources Code, Chapter 7.8, Division 2) directs the California Department of Conservation, Division of Mines and Geology (DMG) to delineate seismic hazard zones. The purpose of the Act is to reduce the threat to public health and safety and to minimize the loss of life and property by identifying and mitigating seismic hazards. Cities, counties, and state agencies are directed to use the seismic hazard zone maps in their land-use planning and permitting processes. The Act requires that site-specific geotechnical investigations be performed prior to permitting most urban development projects within the hazard zones. Evaluation and mitigation of seismic hazards are to be conducted under guidelines established by the California State Mining and Geology Board (1997; also available on the Internet at **http://www.consrv.ca.gov/dmg/pubs/sp/117/**).

The Act also directs SMGB to appoint and consult with the Seismic Hazards Mapping Act Advisory Committee (SHMAAC) in developing criteria for the preparation of the seismic hazard zone maps. SHMAAC consists of geologists, seismologists, civil and structural engineers, representatives of city and county governments, the state insurance commissioner and the insurance industry. In 1991 SMGB adopted initial criteria for delineating seismic hazard zones to promote uniform and effective statewide implementation of the Act. These initial criteria provide detailed standards for mapping regional liquefaction hazards. They also directed DMG to develop a set of probabilistic seismic maps for California and to research methods that might be appropriate for mapping earthquake-induced landslide hazards.

In 1996, working groups established by SHMAAC reviewed the prototype maps and the techniques used to create them. The reviews resulted in recommendations that the 1) process for zoning liquefaction hazards remain unchanged and that 2) earthquake-induced landslide zones be delineated using a modified Newmark analysis.

This Seismic Hazard Evaluation Report summarizes the development of the hazard zone map for each area. The process of zoning for liquefaction uses a combination of Quaternary geologic mapping, historic high-water-table information, and subsurface geotechnical data. The process for zoning earthquake-induced landslides incorporates earthquake loading, existing landslide features, slope gradient, rock strength, and geologic structure. Probabilistic seismic hazard maps, which are the underpinning for delineating seismic hazard zones, have been prepared for peak ground acceleration, mode magnitude, and mode distance with a 10% probability of exceedance in 50 years (Petersen and others, 1996) in accordance with the mapping criteria.

This evaluation report summarizes seismic hazard zone mapping for potentially liquefiable soils and earthquake-induced landslides in the El Monte 7.5-Minute Quadrangle (scale 1:24,000).

SECTION 1
LIQUEFACTION EVALUATION REPORT

Liquefaction Zones in the El Monte 7.5-Minute Quadrangle, Los AngelesCounty, California

By
Ralph C. Loyd

California Department of Conservation
Division of Mines and Geology

PURPOSE

The Seismic Hazards Mapping Act (the Act) of 1990 (Public Resources Code, Chapter 7.8, Division 2) directs the California Department of Conservation, Division of Mines and Geology (DMG) to delineate Seismic Hazard Zones. The purpose of the Act is to reduce the threat to public health and safety and to minimize the loss of life and property by identifying and mitigating seismic hazards. Cities, counties, and state agencies are directed to use the seismic zone maps in their land-use planning and permitting processes. The Act requires that site-specific geotechnical investigations be performed prior to permitting most urban development projects within the hazard zones. Evaluation and mitigation of seismic hazards are to be conducted under guidelines established by the California State Mining and Geology Board (1997; also available on the Internet at http://www.consrv.ca.gov/pubs/sp/117/).

This evaluation report summarizes seismic hazard zone mapping for potentially liquefiable soils in the El Monte 7.5-minute Quadrangle (scale 1:24,000). This section and Section 2 addressing earthquake-induced landslides, are part of a series that will summarize development of similar hazard zone maps in the state (Smith, 1996). Additional information on seismic hazards zone

mapping in California can be accessed on DMG's Internet homepage:
http://www.consrv.ca.gov/dmg/shezp/

BACKGROUND

Liquefaction-induced ground failure has historically been a major cause of earthquake damage in southern California. During the 1971 San Fernando and 1994 Northridge earthquakes, significant damage to roads, utility pipelines, buildings, and other structures in the Los Angeles area was caused by liquefaction-induced ground displacement.

Localities most susceptible to liquefaction-induced damage are underlain by loose, water-saturated granular sediments within 40 feet of the ground surface. These geological and ground-water conditions exist in parts of southern California, most notably in some densely populated valley regions and alluviated floodplains. In addition, the opportunity for strong earthquake ground shaking is high because of the many nearby active faults. The combination of these factors constitutes a significant seismic hazard in the southern California region, including the densely populated area encompassed by the El Monte 7.5-minute Quadrangle.

SCOPE AND LIMITATIONS

Evaluation for potentially liquefiable soils is generally confined to areas covered by Quaternary sedimentary deposits. Such areas consist mainly of alluviated valleys, floodplains, and canyon regions. The evaluation is based on earthquake ground shaking, surface and subsurface lithology, geotechnical soil properties, and ground-water depth data, most of which are gathered from a variety of sources. The quality of the data used varies. Although selection of data used in this evaluation was rigorous, the state of California and the Department of Conservation make no representations or warranties regarding the accuracy of the data obtained from outside sources.

Liquefaction zone maps are intended to prompt more detailed, site-specific geotechnical investigations as required by the Act. As such, liquefaction zone maps identify areas where the potential for liquefaction is relatively high. They do not predict the amount or direction of liquefaction-related ground displacements, or the amount of damage to facilities that may result from liquefaction. Factors that control liquefaction-induced ground failure are the extent, depth and thickness of liquefiable sediments, depth to ground water, rate of drainage, slope gradient, proximity to free-face conditions, and intensity and duration of ground shaking. These factors must be evaluated on a site-specific basis to determine the potential for ground failure at any given project site.

Information developed in the study is presented in two parts: physiographic, geologic, and hydrologic conditions in PART I, and liquefaction potential, opportunity, susceptibility, and zoning evaluations in PART II.

PART I

STUDY AREA LOCATION AND PHYSIOGRAPHY

The El Monte Quadrangle covers an area of about 62 square miles in east-central Los Angeles County. The study area lies in the densely populated western San Gabriel Valley and includes all of the cities of Temple City, San Gabriel, Rosemead, and South El Monte, most of the City of El Monte, and parts of Alhambra, San Marino, Monterey Park, Montebello, Pico Rivera, Arcadia, Monrovia, Industry, Baldwin Park, Commerce, and Whittier. A small patch of unincorporated Los Angeles County land lies between San Marino and Arcadia and larger areas of county land are located in the southeastern quarter of the quadrangle. Major transportation routes traversing the El Monte Quadrangle include the San Bernardino Freeway (I-10), the Pomona Freeway (State Highway 60), and the San Gabriel River Freeway (I-605).

The San Gabriel Valley is a sediment-filled, east-trending structural trough situated along the southern flank of the San Gabriel Mountains. The San Gabriel Mountains are a major component of the Transverse Ranges geomorphic province of California and are comprised largely of plutonic and metamorphic rocks. In the El Monte Quadrangle, the southern boundary of San Gabriel Valley is defined by the Puente and Montebello hills, which are comprised of Teritary marine and nonmarine sedimentary rocks. These highland areas are separated by the Whittier Narrows, through which the nearly converging Rio Hondo and the San Gabriel rivers flow.

GEOLOGIC CONDITIONS

Surface Geology

Quaternary geologic units exposed in the El Monte Quadrangle were mapped in detail by McCalpin (unpublished) and Tan (1997). Their maps are based on stratigraphic, geomorphic, and pedologic criteria - namely relative stratigraphic position, environment of deposition, relative degree of erosion, soil type, soil development, and texture (grain size). Both maps were employed in the evaluation of liquefaction susceptibility of the El Monte Quadrangle.

Map unit nomenclature applied on the accompanying geologic map (Plate 1.1) follows the format developed by the Southern California Areal Mapping Project (SCAMP: Morton and Kennedy, 1989). Plate 1.1 shows that most of the study area is covered by valley alluvial sediments of Quaternary age. In the northwestern half of the quadrangle, these deposits consist of varying amounts of sand, gravel, and silt layers that are incorporated within large, composite alluvial fans associated with the Alhambra, Rubio, Eaton, Arcadia, Santa Anita, and Sawpit washes. In the southeastern half of the study area, flood plain and overbank deposits associated with the San Gabriel and Rio Hondo rivers constitute most of the surficial deposits. The general mineralogy of the Quaternary sediments reflects the composition of Pre-Tertiary crystalline bedrock units exposed in the San Gabriel Mountains to the north and, to a lesser extent, Tertiary sedimentary units exposed in the Montebello Hills and Puente Hills to the south.

Subsurface Geology and Geotechnical Characteristics

Over 260 borehole logs available within the study area were examined and related to the mapped surface geologic units. Subsurface data used for this study include borehole logs collected from the California Department of Transportation (CalTrans), the California Department of Water Resources, the Regional Water Quality Control Board, Los Angeles County Flood Control files by U.S. Geological Survey staff, DMG files of seismic reports for hospital and school sites, and a database of shear wave velocity measurements originally compiled by Walter Silva (Wills and Silva, 1998). Locations and geotechnical data from borehole logs were entered into the DMG Geographic Informaition System (GIS) database. Locations of all exploratory boreholes considered in this investigation are shown on Plate 1.2.

Construction of cross sections using data reported on the borehole logs enabled staff to relate soil engineering properties to various depositonal units, to correlate soil types from one borehole to another, and to extrapolate geotechnical data into outlying areas containing similar soils.

GROUND-WATER CONDITIONS

Liquefaction hazard mapping focuses on areas historically characterized by ground-water depths of 40 feet or less. Accordingly, a ground-water evaluation was performed in the El Monte Quadrangle to determine the presence and extent of historically shallow ground water. Data required to conduct the evaluation were obtained from technical publications, geotechnical boreholes, and water-well logs dating back to the turn-of-the-century, namely 1904 ground-water contour maps (Mendenhall, 1908), 1944 ground- water contour maps (California Department of Water Resources, 1966), and ground- water level measurements reported in compiled 1960-1997 geotechnical borehole logs.

The evaluation showed that the 1904 and 1944 ground-water levels within the El Monte Quadrangle were similarly high. Both sets of maps demonstrate that shallow-water conditions (less than 40 feet depth) exist over a large area (28 square miles within the El Monte Quadrangle) in the vicinity of the Whittier Narrows (Plate 1.2). Ground-water levels from the 1960-1997 geotechnical borehole logs generally are 5-10 feet deeper than the earlier measurements in Whittier Narrows and southward. Just to the north, the levels tend to be 30-50 feet deeper than they were in the first half of the century.

Where records were examined, ground water is also relatively shallow in restricted drainages within the Puente Hills and Montebello Hills. In general, it appears that relatively shallow and impermeable bedrock underlying the stream canyon sediments results in a shallow water table. These sediments can also remain saturated for long periods of time during wet seasons.

PART II

EVALUATING LIQUEFACTION POTENTIAL

Liquefaction occurs in water saturated sediments during moderate to great earthquakes. Liquefied sediments are characterized by a loss of strength and may fail, causing damage to buildings, bridges, and other such structures. A number of methods for mapping liquefaction hazard have been proposed; Youd (1991) highlights the principal developments and notes some of the widely used criteria. Youd and Perkins (1978) demonstrate the use of geologic criteria as a qualitative characterization of susceptibility units, and introduce the mapping technique of combining a liquefaction susceptibility map and a liquefaction opportunity map to produce liquefaction potential. Liquefaction susceptibility is a function of the capacity of sediments to resist liquefaction and liquefaction opportunity is a function of the seismic ground shaking intensity. The application of the Seed Simplified Procedure (Seed and Idriss, 1971) for evaluating liquefaction potential allows a quantitative characterization of susceptibility of geologic units. Tinsley and others (1985) applied a combination of the techniques used by Seed and others (1983) and Youd and Perkins (1978) for mapping liquefaction hazards in the Los Angeles region. Following criteria adopted by the California State Mining and Geology Board (in press), the method applied in this study for evaluating liquefaction potential is similar to that of Tinsley and others (1985) combining geotechnical data analyses, and geologic and hydrologic mapping, but follows criteria adopted by the California State Mining and Geology Board (in press).

LIQUEFACTION OPPORTUNITY

According to the criteria adopted by the California State Mining and Geology Board (in press), liquefaction opportunity is a measure, expressed in probabilistic terms, of the potential for ground shaking strong enough to generate liquefaction. Analyses of in-situ liquefaction resistance require assessment of liquefaction opportunity. The minimum level of seismic excitation to be used for such purposes is the level of peak ground acceleration (PGA) with a 10% probability of exceedance over a 50-year period. The earthquake magnitude is the magnitude that contributes most to the acceleration.

For the El Monte Quadrangle, peak accelerations of 0.46 g to 0.57 g resulting from earthquakes of magnitude 6.7 to 7.0 were used for liquefaction analyses. The PGA and magnitude values were derived from maps prepared by Petersen and others (1996) and Cramer and Petersen (1996), respectively. See the ground motion portion (section 3) of this report for further details.

LIQUEFACTION SUSCEPTIBILITY

Liquefaction susceptibility reflects the relative resistance of soils to loss of strength when subjected to ground shaking. Primarily, physical properties and conditions of soil such as sediment grain-size distribution, compaction, cementation, saturation, and depth govern the degree of resistance. Soils that lack resistance (susceptible soils) are typically saturated, loose sandy sediments. Soils resistant to liquefaction include all soil types that are dry or sufficiently dense.

DMG's map inventory of areas containing soils susceptible to liquefaction begins with evaluation of geologic maps, cross-sections, geotechnical test data, geomorphology, and ground-water hydrology. Soil-property and soil-condition factors such as type, age, texture, color, and consistency, along with historic depths to ground water are used to identify, characterize, and correlate susceptible soils. Because Quaternary geologic mapping is based on similar soil observations, findings can be related to the map units. A qualitative susceptible soil inventory is outlined below and summarized in Table 1.1.

As discussed in the Geologic Conditions section of this report, young Quaternary geologic units, which cover most of the El Monte Quadrangle (Plate 1.1; Table 1.2), are dominated by loose to moderately dense sandy sediments. Where saturated within 40 feet of the ground surface (Plate 1.2), these deposits are judged to be susceptible to liquefaction. Such conditions prevail over an area covering about 28 square miles, or almost one-half of the El Monte Quadrangle.

Quantitative Liquefaction Analysis

DMG performs quantitative analysis of geotechnical data to evaluate liquefaction potential using the Seed Simplified Procedure (Seed and Idriss, 1971; Seed and others, 1983; Seed and Harder, 1990; Youd and Idriss, 1997). This procedure calculates soil resistance to liquefaction, expressed in terms of cyclic resistance ratio (CRR) based on standard penetration test (SPT) results, ground-water level, soil density, moisture content, soil type, and sample depth. CRR values are then compared to calculated earthquake-generated shear stresses, expressed in terms of cyclic stress ratio (CSR). The factor of safety (FS) relative to liquefaction is: FS=CRR/CSR. FS, therefore, is a quantitative measure of liquefaction potential. Generally, a factor of safety of 1.0 or less, where CSR equals or exceeds CRR, indicates the presence of potentially liquefiable soil. DMG uses FS, as well as other considerations such as slope, free face conditions, and thickness and depth of potentially liquefiable soil, to construct liquefaction potential maps, which then directly translate to Zones of Required Investigation.

Map Unit	Age	Environment of Deposition	Primary Textures	General Consistency	Susceptible to Liquefaction?*
Qw	latest Holocene	active stream channels	sand, gravel, cobbles	very loose to loose	yes
Qf	latest Holocene	active alluvial fan deposits	sand, silt gravel	very loose to loose	yes
Qa	latest Holocene	active alluvial basin deposits	Sand, silt, clay	very loose to loose	yes
Qyf1-4	Holocene to latest Pleistocene	younger alluvial fan deposits	Gravel, sand, silt	loose to moderately dense	yes
Qya1-4	Holocene to latest Pleistocene	younger alluvial basin deposits	sand, silt, clay	loose to moderately dense	yes
Qof	Late Pleistocene	older alluvial fan deposits	sand, gravel, silt, clay	dense to very dense	not likely
Qoa	late Pleistocene	older alluvial basin deposits	sand, silt, clay	dense to very dense	not likely
Qvoa	Pleistocene	very old alluvial basin deposits	gravel, sand, silt, clay	dense to very dense	not likely

*** When saturated.**

Table 1.1. General geotechnical characteristics and liquefaction susceptibility of Quaternary sedimentary deposits in the El Monte Quadrangle.

Of the 264 geotechnical borehole logs reviewed in this study (Plate 1.2), 152 include blow-count data from SPT's or from penetration tests that allow reasonable blow count translations to SPT-equivalent values. Non-SPT values, such as those resulting from the use of 2-inch or 2 1/2-inch inside diameter ring samplers, were translated to SPT-equivalent values if reasonable factors could be used in conversion calculations. Few borehole logs, however, include all of the information (soil density, moisture content, sieve analysis, etc) required for an ideal Seed Simplified Analysis. For boreholes having acceptable penetration tests, liquefaction analysis is performed using either logged density, moisture, and sieve test values or average test values of similar materials.

LIQUEFACTION ZONES

Criteria for Zoning

The areas underlain by late Quaternary geologic units were included in liquefaction zones using the criteria adopted by the California State Mining and Geology Board (in press). Under those criteria, liquefaction zones are areas meeting one or more of the following:

1. Areas known to have experienced liquefaction during historic earthquakes.

2. All areas of uncompacted fills containing liquefaction susceptible material thatare saturated, nearly saturated, or may be expected to become saturated.

3. Areas where sufficient existing geotechnical data and analyses indicate that the soils are potentially liquefiable

4. Areas where existing geotechnical data are insufficient**.**

In areas of limited or no geotechnical data, susceptibility zones may be identified by geologic criteria as follows:

a) Areas containing soil deposits of late Holocene age (current river channels and their historic floodplains, marshes and estuaries), where the M7.5-weighted peak acceleration that has a 10% probability of being exceeded in 50 years is greater than or equal to 0.10 g and the water table is less than 40 feet below the ground surface; or

b) Areas containing soil deposits of Holocene age (less than 11,000 years), where the M7.5-weighted peak acceleration that has a 10% probability of being exceeded in 50 years is greater than or equal to 0.20 g and the historic high water table is less than or equal to 30 feet below the ground surface; or

c) Areas containing soil deposits of latest Pleistocene age (between 11,000 years and 15,000 years), where the M7.5-weighted peak acceleration that has a 10% probability of being exceeded in 50 years is greater than or equal to 0.30 g and the historic high water table is less than or equal to 20 feet below the ground surface.

Application of SMGB criteria for liquefaction zoning in the El Monte Quadrangle is summarized below.

Areas of Past Liquefaction

No areas of documented historic liquefaction in the El Monte Quadrangle are known. Areas showing evidence of paleoseismic liquefaction have not been reported.

Artificial Fills

Mapped artificial fill sites in the El Monte Quadrangle include flood-control basin dams, river levees, and developmental slope grading. Although these fills were certainly properly engineered, seismic hazard zoning for liquefaction at these localities is governed by the liquefaction susceptibility of natural soils underlying the fill sites.

Areas with Existing Geotechnical Data

Sufficient geologic and geotechnical data exist for DMG to adequately evaluate liquefaction potential of alluvial sediments throughout the El Monte Quadrangle. DMG's liquefaction susceptible soil inventory and quantitative analyses of geotechnical data in the El Monte Quadrangle indicate that all Holocene and modern soils saturated within 40 feet of the ground surface are potentially liquefiable. These conditions are present over a 28-square-mile area, almost one-half of the quadrangle. Accordingly, DMG delineates this area as a Zone of Required Investigation.

Areas without Existing Geotechnical Data

No areas within the El Monte Quadrangle are zoned on the basis of SMGB criteria for areas where geotechnical data are lacking or insufficient.

ACKNOWLEDGMENTS

The author would like to thank the staff at the California Department of Transportation (CalTrans), the Southern District office of the California Department of Water Resources, and the Los Angeles Regional Water Quality Control Board for their assistance in the collection of subsurface borehole data. We thank James P. McCalpin for sharing his modern Quaternary mapping of the quadrangle and John Tinsley, U. S. Geological Survey, for facilitating access to digital copies of McCalpin's maps and providing geotechnical data. Special thanks to Bob Moskovitz, Teri McGuire, and Scott Shepherd of DMG for their GIS operations support and to Barbara Wanish for graphic layout and reproduction of Seismic Hazard Zone maps.

REFERENCES

California Department of Water Resources, 1966, Planned utilization of ground water basins, San Gabriel Valley, Appendix A: Geohydrology: Bulletin No. 104-2, 229 p., map scale 1:125.000.

California State Mining and Geology Board, 1997, Guidelines for evaluating and mitigating seismic hazards in California: California Department of Conservation, Division of Mines and Geology, Special Publication 117, 74 p.

California State Mining and Geology Board, in press, Criteria for delineating seismic hazard zones: California Department of Conservation, Division of Mines and Geology, Special Publication 118, 21 p.

Cramer, C.H. and Petersen, M.D., 1996, Predominant seismic source distance and magnitude maps for Los Angeles, Orange, and Ventura counties, California: Bulletin of Seismological Society of America, v. 86, no. 5, p. 1,645-1,649.

McCalpin, J.P., unpublished, Digital geologic map of the El Monte 7.5-minute Quadrangle, Los Angeles County, California: contracted for the Southern California Areal Mapping Project (SCAMP), resolution 1:24000.

Mendenhall, W.C., 1908, Ground waters and irrigation enterprises in the foothill belt, southern California: United States Geological Survey Water-Supply Paper 219, 180 p., 9 plates, map scale 1:62500.

Morton, D.M. and Kennedy, M.P., 1989, A southern California digital 1:100,000-scale geologic map series: The Santa Ana Quadrangle, The first release: Geological Society of America Abstracts with Programs v. 21, no. 6, p. A107-A108.

Petersen, M.D., Cramer, C.H., Bryant, W. A., Reichle, M. S. and Toppozada, T.R., 1996, Preliminary seismic hazard assessment for Los Angeles, Ventura, and Orange counties, affected by the 17 January 1994 Northridge earthquake: Bulletin of the Seismological Society of America, v. 86, no. 1B, p. S247-S261.

Seed, H.B. and Idriss, I. M., 1971, Simplified procedure for evaluating soil liquefaction potential: Journal of the Soil Mechanics and Foundations Division of ASCE, v. 97: SM9, p. 1,249-1,273.

Seed, H.B., Idriss, I. M. and Arango, Ignacio, 1983, Evaluation of liquefaction potential using field performance data: Journal of Geotechnical Engineering, v. 109, no. 3, p. 458-482.

Seed, R.B. and Harder, L.F., 1990, SPT-based analysis of cyclic pore pressure generation and undrained residual strength: Proceedings of the H. Bolton Seed Memorial Symposium, v. 2, p. 351-376.

Smith, T.C., 1996, Preliminary maps of seismic hazard zones and draft guidelines for evaluating and mitigating seismic hazards: California Geology, v. 49, no. 6, p. 147-150.

Tan, S.S., 1997, Geologic map of the El Monte 7.5-minute Quadrangle, Los Angeles County, California: California Department of Conservation, Division of Mines and Geology – Southern California Areal Mapping Project, digital map, scale 1:24,000.

Tinsley, J.C. and Fumal, T.E., 1985, Mapping Quaternary sedimentary deposits for areal variations in shaking response, *in* Ziony, J. I., *editor*, Evaluating earthquake hazards in the Los Angeles Region -- An earth-science perspective: U.S. Geological Survey Professional Paper 1360, p. 101 -125.

Tinsley, J.C., Youd, T. L., Perkins, D. M. and Chen, A.T.F., 1985, Evaluating liquefaction potential, *in* Ziony, J.I. *editor*, Evaluating earthquake hazards in the Los Angeles region -- an earth science perspective: U.S. Geological Survey Professional Paper 1360, p. 263-316.

Wills, C.J. and Silva, Walter, 1998, Shear wave velocity characteristics of geologic units in California: Earthquake Spectra, v. 14, p. 533-556.

Youd, T.L., 1991, Mapping of earthquake-induced liquefaction for seismic zonation: Earthquake Engineering Research Institute, Proceedings, Fourth International Conference on Seismic Zonation, v. 1, p. 111-138.

Youd, T.L. and Idriss, I.M., 1997, Proceedings of the NCEER workshop on evaluation of liquefaction resistance of soils: Technical Report NCEER-97-0022

Youd, T.L. and Perkins, D.M. 1978, Mapping liquefaction-induced ground failure potential: Journal of Geotechnical Engineering, v. 104, p. 433-446.

SECTION 2
EARTHQUAKE-INDUCED LANDSLIDE EVALUATION REPORT

Earthquake-Induced Landslide Zones in the El Monte 7.5-Minute Quadrangle, Los Angeles County, California

By
Florante G. Perez, Timothy P. McCrink, Siang S. Tan, and Rick I. Wilson

California Department of Conservation
Division of Mines and Geology

PURPOSE

The Seismic Hazards Mapping Act (the Act) of 1990 (Public Resources Code, Chapter 7.8, Division 2) directs the California Department of Conservation, Division of Mines and Geology (DMG) to delineate Seismic Hazard Zones. The purpose of the Act is to reduce the threat to public health and safety and to minimize the loss of life and property by identifying and mitigating seismic hazards. Cities, counties, and state agencies are directed to use the seismic hazard zone maps in their land-use planning and permitting processes. The Act requires that site-specific geotechnical investigations be performed prior to permitting most urban development projects within the hazard zones. Evaluation and mitigation of seismic hazards are to be conducted under guidelines established by the California State Mining and Geology Board (1997; also available on the Internet at http://www.consrv.ca.gov/pubs/sp/117/).

This evaluation report summarizes seismic hazard zone mapping for earthquake-induced landslides in the El Monte 7.5-minute Quadrangle (scale 1:24,000). This section and Section 1 addressing liquefaction, are part of a series that will summarize development of similar hazard zone maps in the state (Smith, 1996). Additional information on seismic hazard zone mapping in California can be accessed on DMG's Internet homepage: http://www.consrv.ca.gov/dmg/shezp/

BACKGROUND

Landslides triggered by earthquakes have historically been a major cause of earthquake damage. Landslides triggered by the 1971 San Fernando, 1989 Loma Prieta, and 1994 Northridge earthquakes were responsible for destroying or damaging numerous homes and other structures, blocking major transportation corridors, and damaging various types of life-line infrastructure. Typically, areas most susceptible to earthquake-induced landslides are on steep slopes and on or adjacent to existing landslide deposits, especially if the earth materials in these areas are composed of loose colluvial soils, or poorly cemented or highly fractured rock. These geologic and terrain conditions exist in many parts of southern California, most notably in hilly areas already developed or currently undergoing development. In addition, the opportunity for strong earthquake ground shaking is high because of the many nearby active faults. The combination of these factors constitutes a significant seismic hazard in the southern California region, which includes the El Monte Quadrangle.

SCOPE AND LIMITATIONS

The methodology used to make this map is based on earthquake ground-shaking estimates, geologic material-strength characteristics and slope gradient. These data are gathered primarily from a variety of outside sources; thus the quality of the data is variable. Although the selection of data used in this evaluation was rigorous, the state of California and the Department of Conservation make no representations or warranties regarding the accuracy of the data gathered from outside sources.

Earthquake-induced landslide zone maps are intended to be used to prompt more detailed, site-specific geotechnical investigations as required by the Act. As such, these zone maps identify areas where the potential for earthquake-induced landslides is relatively high. Earthquake-generated ground failures that are not addressed by this map include those associated with ridge-top spreading and shattered ridges. No attempt has been made to map potential run-out areas of triggered landslides. It is possible that such run-out areas may extend beyond the zone boundaries. The potential for ground failure resulting from liquefaction-induced lateral spreading of alluvial materials, considered by some to be a form of landsliding, is not specifically addressed by the earthquake-induced landslide zone or this report. See Section 1, Liquefaction Evaluation Report for the El Monte Quadrangle, for more information on the delineation of liquefaction zones.

Information developed in the study is presented in two parts: physiographic, and geologic conditions in PART I, and ground shaking opportunity, landslide hazard potential and zoning evaluations in PART II.

PART I

STUDY AREA LOCATION AND PHYSIOGRAPHY

The El Monte Quadrangle covers an area of about 62 square miles in east-central Los Angeles County. The study area lies in densely populated western San Gabriel Valley and includes all of the cities of Temple City, San Gabriel, Rosemead, and South El Monte, most of the City of El Monte, and parts of Alhambra, San Marino, Monterey Park, Montebello, Pico Rivera, Arcadia, Monrovia, Industry, Baldwin Park, Commerce, and Whittier. A small patch of unincorporated Los Angeles County land lies between San Marino and Arcadia and larger areas of county land are located in the southeastern quarter of the quadrangle. Major transportation routes traversing the El Monte Quadrangle include the San Bernardino Freeway (I-10), the Pomona Freeway (State Highway 60), and the San Gabriel River Freeway (I-605).

The San Gabriel Valley is a sediment-filled, east-trending structural trough situated along the southern flank of the San Gabriel Mountains. The San Gabriel Mountains are a major component of the Transverse Ranges geomorphic province of California and are comprised largely of plutonic and metamorphic rocks. In the El Monte Quadrangle, the southern boundary of San Gabriel Valley is defined by the Puente and Montebello hills, which are comprised of Tertiary marine and nonmarine sedimentary rocks. These highland areas are bisected by the Rio Hondo and the San Gabriel River, which nearly converge at the Whittier Narrows, the site of a major flood control basin and county recreation area.

GEOLOGIC CONDITIONS

Surface and Bedrock Geology

For the El Monte Quadrangle, a geologic map was compiled and digitized by the Southern California Mapping Project (SCAMP: Morton and Kennedy, 1989) from original mapping by Tan (1997). The digital geologic map obtained from SCAMP was modified to reflect the most recent mapping in the area. In the field, observations were made of exposures, aspects of weathering, and general surface expression of the geologic units. In addition, the relation of the various geologic units to development and abundance of landslides was noted.

The oldest rock unit mapped in the El Monte Quadrangle is the middle-upper Miocene Puente Formation consisting of a very thick sequence of marine sandstone, siltstone, shale, and pebble conglomerate. It occurs in a very limited extent in the southeastern corner of the quadrangle. This formation is subdivided into four members but only the upper three members are exposed. The Soquel Member (Tpsq) consists of massive to, locally, thick-bedded sandstone with interbedded clayey siltstone and pebble-cobble conglomerate. The Yorba Member (Tpy) is made up of interbedded sandy and diatomaceous siltstone containing thin beds of limestone and thin-bedded to massive sandstone. The Yorba and Soquel members are exposed only near the southern terminus of the Workman Hill Fault. The uppermost member, the Sycamore Canyon

Member (Tpsc), consisting of interlayered micaceous siltstone and coarse-grained sandstone with interbedded conglomerate (Tpscc) crops out in the eastern and southern portions of the Puente Hills.

Overlying the Puente Formation is the Pliocene Fernando Formation (Tf) that consists of repetitiously interbedded fine to coarse clastic marine strata that is divided into lower (Tfl) and upper (Tfu) members on the basis of an extensive erosional unconformity and lithologic variations (Yerkes and others, 1965). South of Rio Hondo Junior College, the lower member consists of alternating massive silty sandstone and pebble conglomerate (Tflc). The upper member crops out in the northern portion of the Puente Hills and in the Montebello Hills. It is composed of friable silty and pebbly sandstone interfingering with thin beds of siltstone and massive pebble conglomerate (Tfuc).

Quaternary deposits cover the floor and margins of San Gabriel Valley, including stream channels, alluvial fans, and flood plains. They are composed of active channel wash (Qw1a, Qw1ag, Qw1g, Qw1s, Qwa, Qwag), younger alluvial fan deposits (Qyfa, Qyfag, Qyfg, Qyfs), and older alluvial fan and terrace deposits (Qof1a, Qof1ag, Qof2a, Qof2ag, Qof3s, Qof4s, Qof4sg). Landslides (Qls, Qls?) are widespread in the southern portion of the quadrangle. A more detailed discussion of the Quaternary deposits in the El Monte Quadrangle can be found in Section 1.

Geologic Material Strength

To evaluate the stability of geologic materials under earthquake conditions, they must first be ranked on the basis of their overall shear strength. Shear strength data for the rock units identified on the geologic map were obtained from geotechnical reports prepared by consultants and on file with the local government permitting departments, from the Corporate Library of Leighton and Associates, Inc., the City of Monterey Park, and the Los Angeles County Department of Public Works (see Appendix A). The locations of rock and soil samples taken for shear testing are shown on Plate 2.1.

Shear strength data gathered from the above sources were compiled for each mapped geologic unit, and subdivided for fine-grained and coarse-grained lithologies, if appropriate. Geologic units were grouped on the basis of average angle of internal friction (average f) and lithologic character. Geologic formations that had little or no shear test information were added to existing groups on the basis of lithologic and stratigraphic similarities.

To subdivide mapped geologic formations that have both fine-grained and coarse-grained lithologies, we assumed that where stratigraphic bedding dips into a slope (favorable bedding) the coarse-grained material strength dominates, and where bedding dips out of a slope (adverse bedding) the fine-grained material strength dominates. We then used structural information from the geologic map (see "Structural Geology") and terrain data in the form of slope gradient and aspect, to identify areas with a high potential for containing adverse bedding conditions. These areas, located on the map, were then used to modify the geologic material-strength map to reflect the anticipated lower shear strength for the fine-grained materials.

The results of the grouping of geologic materials in the El Monte Quadrangle are in Tables 2.1 and 2.2.

EL MONTE QUADRANGLE
SHEAR STRENGTH GROUPS STATISTICS

	Formation Name	Number of Tests	Mean Phi Value	Group Phi Mean/Median (degrees)	Group C Mean/Median (psf)	No Data Similar Lithology	Phi Values Used in Stability Analysis
Group 1	Tfu(crse) Qof	7 8	34.0 33.6	33.8/33.0	108/107	Tfuc,Tpsq Qof1a,Qof1ag, Qof2a,Qof2ag Qof3s,Qof4s,Qof4sg	34
Group 2	Qyf	7	31.6	31.7/31.5	82/40	Tpscc, Tpsc(crse) Tpy, Qw1a,Qw1ag Qw1g,Qw1s,Qwa Qwag, Qyfa,Qyfag Qyfg,Qyfs	31
Group 3	Tfl(crse) Tfu(fine)	9 3	27.1 26.0	26.8/26.5	671/650	Tflc,Tpsc(fine) Tfuf	26
Group 4	Tfl (fine)	3	21.3	21.3/21.0	916/1000		21
Group 5	Qls					QlsD, QlsP	*12*

Table 2.1. Summary of the Shear Strength Statistics for the El Monte Quadrangle.

EL MONTE QUADRANGLE SHEAR STRENGTH GROUPS				
Group 1	**Group 2**	**Group 3**	**Group 4**	**Group 5**
Tfu (crse) Tfuc,Tpsq Qof1a,Qof1ag Qof2a,Qof2ag Qof3s,Qof4s Qof4sg	Tpsc(crse) Tpscc, Tpy Qw1a,Qw1ag Qw1g,Qw1s,Qwa Qwag,Qyfa,Qyfag Qyfg,Qyfs	Tfl(crse) Tfu(fine),Tflc Tpsc(fine),Tfuf	Tfl(fine)	Qls*D* Qls*P*

Table 2.2. Summary of the Shear Strength Groups for the El Monte Quadrangle.

Structural Geology

Accompanying the digital geologic map were digital files of associated geologic structural data, including bedding and foliation attitudes (strike and dip) and fold axes. We used the structural geologic information provided with the digital geologic map (SCAMP) derived from Tan (1997) to categorize areas of common stratigraphic dip direction and magnitude, similar to the method presented by Brabb (1983). The dip direction category was compared to the slope aspect (direction) category and, if the same, the dip magnitude and slope gradient categories were compared. If the dip magnitude category was less than or equal to the slope gradient category, and the bedding dip was greater than 25% (4:1 slope), the area was marked as a potential adverse bedding area. This information was then used to subdivide mapped geologic units into areas where fine-grained and coarse-grained strengths would be used.

Several north-northwest trending faults transect the El Monte Quadrangle, the most notable of which are the East Montebello, Workman Hill, and Whittier Heights faults. Two parallel faults, the Rio Hondo and Pico faults, that strike to the northwest are located southeast of the quadrangle near Pico Rivera.

Landslide Inventory

The evaluation of earthquake-induced landsliding requires an up-to-date and complete analysis of previously mapped landslides. DMG geologists compiled the existing landslides in the El Monte Quadrangle from published landslide hazard maps by Tan (1988). Then by combining analysis of aerial photos and interpretation of landforms with field observations, all landslides compiled on the map were verified, re-mapped, or deleted during the preparation of the landslide inventory map. The most landslide-prone bedrock unit in the quadrangle is the fine-grained lithology of the lower member of the Fernando Formation. The most stable is the coarse-grained lithology of the upper member of the Fernando Formation. Most of the landslides inventoried are debris slides, block slides, and slumps.

The landslide inventory map was digitized and attributed with information on confidence of interpretation (definite, probable, or questionable) and other properties such as activity, thickness, and associated geologic unit(s). Only those landslides classified in the DMG inventory as definite or probable were incorporated into the hazard-evaluation process. A version of this landslide inventory is included with Plate 2.1.

PART II

EARTHQUAKE-INDUCED LANDSLIDE GROUND SHAKING OPPORTUNITY

Design Strong-Motion Record

The Newmark analysis used in delineating the earthquake-induced landslide zones requires the selection of a design earthquake strong-motion record. For the El Monte Quadrangle, the selection was based on an estimation of probabilistic ground motion parameters for modal magnitude, modal distance, and peak ground acceleration (PGA). The parameters were estimated from maps prepared by DMG for a 10% probability of being exceeded in 50 years (Petersen and others, 1996; Cramer and Petersen, 1996). The parameters used in the record selection are:

Modal Magnitude:	6.9
Modal Distance:	2.6 to 7.5 km
PGA:	0.43 to 0.70 g

The strong-motion record selected was the Channel 3 (north 35 degrees east horizontal component) University of Southern California Station #14 recording from the magnitude 6.7 Northridge earthquake (Trifunac and others, 1994). This record had a source-to-recording site distance of 8.5 km and a PGA of 0.59 g. The selected strong-motion record was not scaled or otherwise modified prior to analysis.

Displacement Calculation

To develop a relationship between the yield acceleration (a_y; defined as the horizontal ground acceleration required to cause the factor of safety to equal 1.0) and Newmark displacements, the design strong-motion record was integrated twice for a given a_y to find the corresponding displacement, and the process repeated for a range of a_y (Jibson, 1993). The resulting curve in Figure 2.1 represents the full spectrum of displacements that can be expected for any combination of geologic material strength and slope angle, as represented by the yield acceleration. We used displacements of 30, 15 and 5 cm as criteria for rating levels of earthquake shaking damage on the basis of the work of Youd (1980), Wilson and Keefer (1983), and the DMG pilot study for earthquake-induced landslides (McCrink and Real, 1996). Applied to the curve in Figure 2.1, these displacements correspond to yield accelerations of 0.076, 0.129 and 0.232 g. Because these yield acceleration values are derived from the design strong-motion record, they represent the ground shaking opportunity thresholds that are significant to the El Monte Quadrangle.

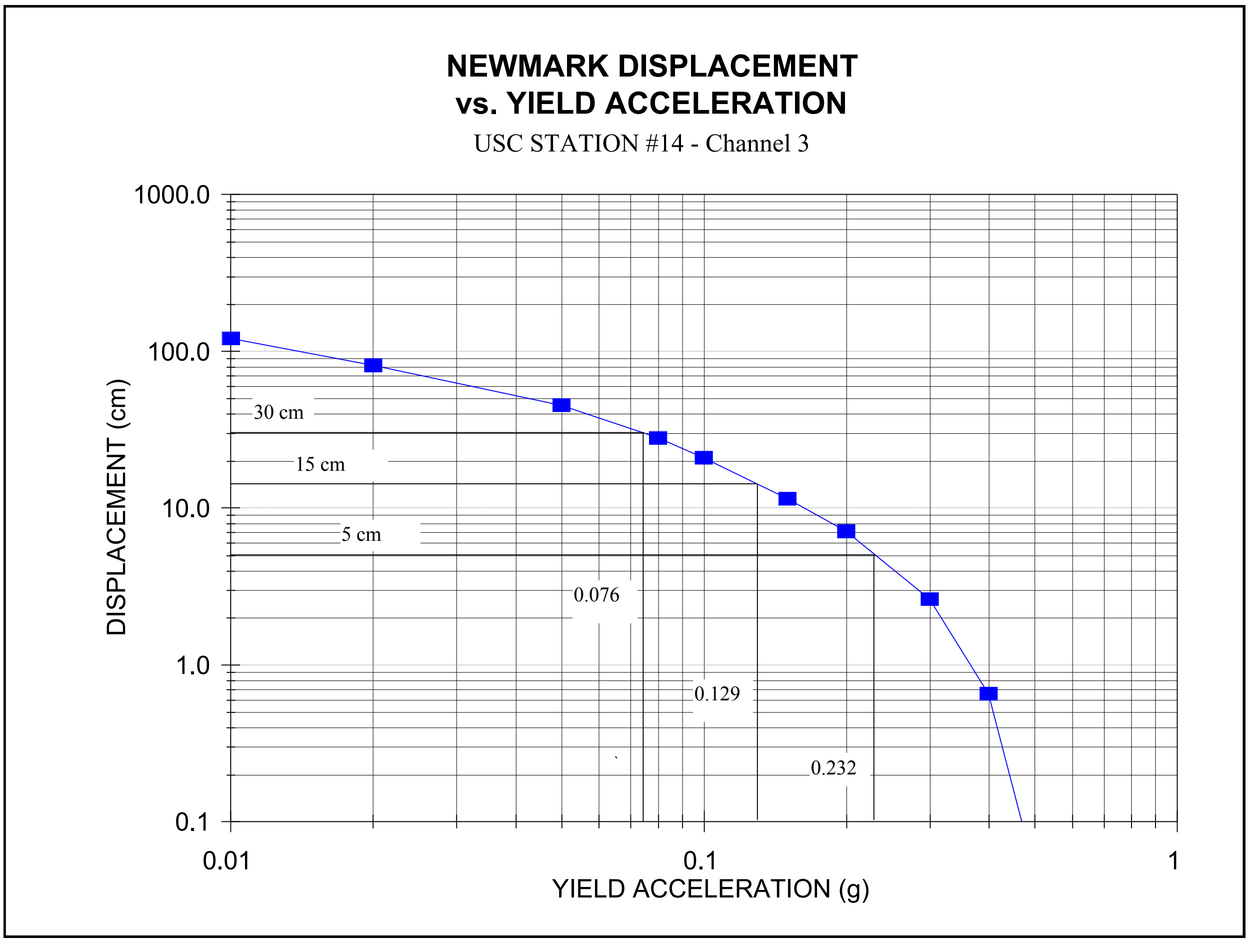

Figure 2.1. Yield Acceleration vs. Newmark Displacement for the USC Station #14 Strong-Motion Record From the 17 January 1994 Northridge, California Earthquake.

EARTHQUAKE-INDUCED LANDSLIDE HAZARD POTENTIAL

Terrain Data

The calculation of slope gradient is an essential part of the evaluation of slope stability under earthquake conditions. To calculate slope gradient for the terrain within the El Monte Quadrangle, a Level 2 digital elevation model (DEM) was obtained from the USGS (U.S. Geological Survey, 1993). This DEM, which was prepared from the 7.5-minute quadrangle contours, has a 10-meter horizontal resolution and a 7.5-meter vertical accuracy. Surrounding quadrangle DEMs were merged with the El Monte DEM to avoid the loss of data at the quadrangle edges when the slope calculations were performed. A peak and pit smoothing process was then performed to remove errors in the elevation points.

To update the topographic base map, areas that have undergone large-scale grading as a part of residential development in the hilly portions of the El Monte Quadrangle were identified. Using 1:40,000-scale NAPP photography taken in May and June, 1994, photogrammetric DEMs covering the graded areas were prepared by the U.S. Bureau of Reclamation with ground control obtained by DMG (USGS, 1994a, 1994b). The photogrammetric DEMs were then merged into the USGS DEM, replacing the areas of out-dated elevation data. Plate 2.1 shows those areas where the topography is updated to 1994 grading conditions.

A slope-gradient map was made from the combined DEMs using a third-order, finite difference, center-weighted algorithm (Horn, 1981). This map was used in conjunction with the geologic strength map in preparation of the earthquake-induced landslide hazard potential map.

Stability Analysis

A slope stability analysis was performed for each geologic material strength group at slope increments of one degree. An infinite-slope failure model under unsaturated slope conditions was assumed. A factor of safety was calculated first, followed by the calculation of yield acceleration from Newmark's equation:

$$a_y = (FS - 1)g \sin \alpha$$

where FS is the Factor of Safety, g is the acceleration due to gravity, and α is the direction of movement of the slide mass, in degrees measured from the horizontal, when displacement is initiated (Newmark, 1965). For an infinite slope failure α is the same as the slope angle.

The yield acceleration calculated by Newmark's equation represents the susceptibility to earthquake-induced failure of each geologic material strength group for a range of slope gradients. The acceleration values were compared with the ground shaking opportunity, defined by Figure 2.1, to determine the earthquake-induced landslide hazard potential. Based on the criteria described in Figure 2.1 above, if the calculated yield acceleration was less than 0.076g, expected displacements could be greater than 30cm, and a HIGH (H on Table 2.3) hazard potential was assigned. Likewise, if the calculated a_y fell between 0.076 and 0.129g a MODERATE (M on Table 2.3) potential was assigned, between 0.129 and 0.232 a LOW (L on Table 2.3) potential was assigned, and if a_y were greater than 0.232g a VERY LOW (VL on Table 2.3) potential was assigned.

Table 2.3 summarizes the results of the stability analyses. The earthquake-induced landslide hazard potential map was prepared by combining the geologic material-strength map and the slope map according to this table.

				El Monte Quadrangle Hazard Potential Matrix					
				Slope					
Geologic	**I**	**II**	**III**	**IV**	**V**	**VI**	**VII**	**VIII**	
Material	**0 to 7**	**8 to 14**	**15 to 23**	**24 to 35**	**36 to 42**	**43 to 52**	**53 to 59**	**>60**	**Percent**
Group	0 TO 4	5 TO 8	9 TO 13	14 TO 19	20 TO 23	24 TO 27	28 TO 30	>31	Degrees
Group 1	**VL**	**VL**	**VL**	**VL**	**VL**	**L**	**M**	**H**	
Group 2	**VL**	**VL**	**VL**	**VL**	**L**	**M**	**H**	**H**	
Group 3	**VL**	**VL**	**VL**	**L**	**M**	**H**	**H**	**H**	
Group 4	**VL**	**VL**	**L**	**M**	**H**	**H**	**H**	**H**	
Group 5	**L**	**H**	**H**	**H**	**H**	**H**	**H**	**H**	

Table 2.3. Hazard Potential Matrix for Earthquake-Induced Landslides in the El Monte Quadrangle. Shaded area indicates the hazard potential levels included in the hazard zone.

EARTHQUAKE-INDUCED LANDSLIDE ZONE

Criteria for Zoning

Earthquake-induced landslide zones were delineated using criteria adopted by the California State Mining and Geology Board (in press). Under those criteria, earthquake-induced landslide zones are areas meeting one or more of the following:

1. Areas known to have experienced earthquake-induced slope failure during historic earthquakes.

2. Areas identified as having past landslide movement, including both landslide deposits and source areas.

3. Areas where CDMG's analyses of geologic and geotechnical data indicate that the geologic materials are susceptible to earthquake-induced slope failure.

Existing Landslides

Studies of the types of landslides caused by earthquakes (Keefer, 1984) show that re-activation of the whole mass of deep-seated landslide deposits is rare. However, it has been observed that the steep scarps and toe areas of existing landslides, which formed as a result of previous landslide movement, are particularly susceptible to earthquake-induced slope failure. In addition, because they have been disrupted during landslide movement, landslide deposits are inferred to be weaker than coherent, undisturbed, adjacent source rocks. Finally, we felt that a long duration, San Andreas fault-type earthquake could be capable of initiating renewed movement in existing deep-seated landslide deposits. Therefore, all existing landslides identified in the inventory with a definite or probable confidence of interpretation were included in the hazard zone.

Geologic and Geotechnical Analysis

On the basis of a DMG pilot study (McCrink and Real, 1996) the earthquake-induced landslide zone includes all areas determined to lie within the High, Moderate and Low levels of hazard potential. Therefore, as shown in Table 2.3, geologic strength group 5 (mapped landslides) is always included in the zone; strength group 4 is in the zone for all slopes greater than 14%; strength group 3 above 23%; strength group 2 above 35%, and strength group 1, the strongest rock types, were zoned for slope gradients above 42%. This results in roughly 4.3% of the land in the El Monte Quadrangle lying within the hazard zone.

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REFERENCES

Brabb, E.E., 1983, Map showing direction and amount of bedding dip of sedimentary rocks in San Mateo County, California: U.S. Geological Survey Miscellaneous Investigations Series Map I-1257C, 1 sheet, scale 1:62,500.

California State Mining and Geology Board, 1997, Guidelines for evaluating and mitigating seismic hazards in California: California Department of Conservation, Division of Mines and Geology, Special Publication 117, 74 p.

California State Mining and Geology Board, in press, Criteria for delineating seismic hazard zones: California Department of Conservation, Division of Mines and Geology, Special Publication 118, 21 p.

Cramer, C.H. and Petersen, M.D., 1996, Predominant seismic source distance and magnitude maps for Los Angeles, Orange and Ventura counties, California: Bulletin of the Seismological Society of America, v. 85, no. 5, p. 1645-1649.

Horn, B.K.P., 1981, Hill shading and the reflectance map: Proceedings of the IEEE, v. 69, no. 1, p. 14-47.

Jibson, R.W., 1993, Predicting earthquake-induced landslide displacements using Newmark's sliding block analysis: Transportation Research Board, National Research Council, Transportation Research Record 1411, 17 p.

Keefer, D.K., 1984, Landslides caused by earthquakes: Geological Society of America Bulletin, v. 95, no. 4, p. 406-421.

McCrink, T.P. and Real, C.R., 1996, Evaluation of the Newmark method for mapping earthquake-induced landslide hazards in the Laurel 7-1/2 minute Quadrangle, Santa Cruz County, California: California Division of Mines and Geology Final Technical Report for U.S. Geological Survey Contract 143-93-G-2334, U.S. Geological Survey, Reston Virginia, 31 p.

Morton, D.M. and Kennedy, M.P., 1989, A southern California digital 1:100,000-scale geologic map series: The Santa Ana Quadrangle, The first release: Geological Society of America Abstracts with Programs v. 21, no. 6, p. A107-A108.

Newmark, N.M., 1965, Effects of earthquakes on dams and embankments: Geotechnique, v. 15, no. 2, p. 139-160.

Petersen, M.D., Cramer, C.H., Bryant, W.A., Reichle, M.S. and Toppozada, T.R., 1996, Preliminary seismic hazard assessment for Los Angeles, Ventura, and Orange counties, California, affected by the January 17, 1994 Northridge earthquake: Bulletin of the Seismological Society of America, v. 86, no. 1B, p. S247-S261.

Smith, T.C., 1996, Preliminary maps of seismic hazard zones and draft guidelines for evaluating and mitigating seismic hazards: California Geology, v. 49, no. 6, p. 147-150.

Tan, S. S., 1988, Landslide hazards in the Puente and San Jose hills, southern California: California Department of Conservation, Division of Mines and Geology, Open-File Report 88-21, 6 plates, 1:24,000.

Tan, S. S., 1997, Geologic map of the El Monte 7.5-minute Quadrangle, Los Angeles County, California: California Department of Conservation, Division of Mines and Geology - Southern California Areal Mapping Project, digital map, scale 1:24,000.

Trifunac, M.D., Todorovska, M.I. and Ivanovic, S.S., 1994, A note on distribution of uncorrected peak ground accelerations during the Northridge, California earthquake of 17 January 1994: Soil Dynamic and Earthquake Engineering, v. 13, no. 3, p. 187-196.

U.S. Geological Survey, 1993, Digital Elevation Models: National Mapping Program, Technical Instructions, Data Users Guide 5, 48 p.

Varnes, D. J., 1978, Slope movement types and processes: Landslide Analysis and Control, Transportation Research Board, National Research Council, Special Report 176, p. 11-33.

Wilson, R.C. and Keefer, D.K., 1983, Dynamic analysis of a slope failure from the 1979 Coyote Lake, California, earthquake: Bulletin of the Seismological Society of America, v. 73, p. 863-877.

Woodford, A. O., 1946, Miocene conglomerates of Puente and San Jose hills, California: American Association of Petroleum Geologists Bulletin, v. 30, p. 514-560.

Yerkes, R. F., McCulloh, T.H., Schoellhamer, J. E. and Vedder, J. G., 1965, Geology of the Los Angeles basin, California -- An introduction: Geological Survey Professional Paper 420-A, 57p.

Youd, T.L., 1980, Ground failure displacement and earthquake damage to buildings: American Society of Civil Engineers Conference on Civil Engineering and Nuclear Power, 2d, Knoxville, Tennessee, 1980, v. 2, p. 7-6-2 to 7-6-26.

AIR PHOTOS

USGS (U.S. Geological Survey), 1994a, NAPP Aerial Photography, Flight 6858, May 31, 1994, Frames 100 to 104, black and white, vertical; scale 1:40,000.

USGS (U.S. Geological Survey), 1994b, NAPP Aerial Photography, Flight 6862, June 1, 1994, Frames 155 to 159, black and white, vertical; scale 1:40,000.

USGS Project GS-VEZS, I.K. Curtis Services, Inc. 1980 Aerial Photographs, flight 1, frames 220-223, flight 2, frames 33-39, black & white, vertical, approximate scale 1:24,000.

APPENDIX A
SOURCES OF ROCK STRENGTH DATA

SOURCE	NUMBER OF TESTS SELECTED
Leighton and Associates, Inc. Corporate	**17**

Library	
City of Monterey Park	**18**
Los Angeles County Department of Public Works, Material Engineering Division files	**11**
Total number of tests considered to characterize the units in the El Monte Quadrangle	**46**

SECTION 3
GROUND SHAKING EVALUATION REPORT

Potential Ground Shaking in the El Monte 7.5-Minute Quadrangle, Los Angeles County, California

By

Mark D. Petersen, Chris H. Cramer, Geoffrey A. Faneros, Charles R. Real and Michael S. Reichle

California Department of Conservation
Division of Mines and Geology

PURPOSE

The Seismic Hazards Mapping Act (the Act) of 1990 (Public Resources Code, Chapter 7.8, Division 2) directs the California Department of Conservation, Division of Mines and Geology (DMG) to delineate Seismic Hazard Zones. The purpose of the Act is to reduce the threat to public health and safety and to minimize the loss of life and property by identifying and mitigating seismic hazards. Cities, counties, and state agencies are directed to use the Seismic Hazard Zone Maps in their land-use planning and permitting processes. The Act requires that site-specific geotechnical investigations be performed prior to permitting most urban development projects within the hazard zones. Evaluation and mitigation of seismic hazards are to be conducted under guidelines established by the California State Mining and Geology Board (1997; also available on the Internet at **http://www.consrv.ca.gov/dmg/pubs/sp/117/**).

This section of the evaluation report summarizes the ground motions used to evaluate liquefaction and earthquake-induced landslide potential for zoning purposes. Included, are ground motion and related maps, a brief overview on how these maps were prepared, precautionary notes concerning their use, and related references. The maps provided herein are presented at a scale of approximately 1:150,000 (scale bar provided on maps), and show the full 7.5- minute quadrangle and portions of the adjacent eight quadrangles. They can be used to assist in the specification of earthquake loading conditions ***for the analysis of ground failure*** according to the “Simple Prescribed Parameter Value” method (SPPV) described in the site investigation guidelines (California State Mining and Geology Board, 1997). Alternatively, they can be used as a basis for comparing levels of ground motion determined by other methods with the statewide standard.

This section and Sections 1 and 2, addressing liquefaction and earthquake-induced landslide hazards, constitute a report series that summarizes development of seismic hazard zone maps in the state. Additional information on seismic hazard zone mapping in California can be accessed on DMG’s Internet homepage: http://www.consrv.ca.gov/dmg/shezp/

EARTHQUAKE HAZARD MODEL

The estimated ground shaking is derived from the seismogenic sources as published in the statewide probabilistic seismic hazard evaluation released cooperatively by the California Department of Conservation, Division of Mines and Geology, and the U.S. Geological Survey (Petersen and others, 1996). That report documents an extensive 3-year effort to obtain consensus within the scientific community regarding fault parameters that characterize the seismic hazard in California. Fault sources included in the model were evaluated for long-term slip rate, maximum earthquake magnitude, and rupture geometry. These fault parameters, along with historical seismicity, were used to estimate return times of moderate to large earthquakes that contribute to the hazard.

The ground shaking levels are estimated for each of the sources included in the seismic source model using attenuation relations that relate earthquake shaking with magnitude, distance from the earthquake, and type of fault rupture (strike-slip, reverse, normal, or subduction). The published hazard evaluation of Petersen and others (1996) only considers uniform firm-rock site conditions. In this report, however, we extend the hazard analysis to include the hazard of exceeding peak horizontal ground acceleration (PGA) at 10% probability of exceedance in 50 years on spatially uniform conditions of rock, soft rock, and alluvium. These soil and rock conditions approximately correspond to site categories defined in Chapter 16 of the Uniform Building Code (ICBO, 1997), which are commonly found in California. We use the attenuation relations of Boore and others (1997), Campbell (1997), Sadigh and others (1997), and Youngs and others (1997) to calculate the ground motions.

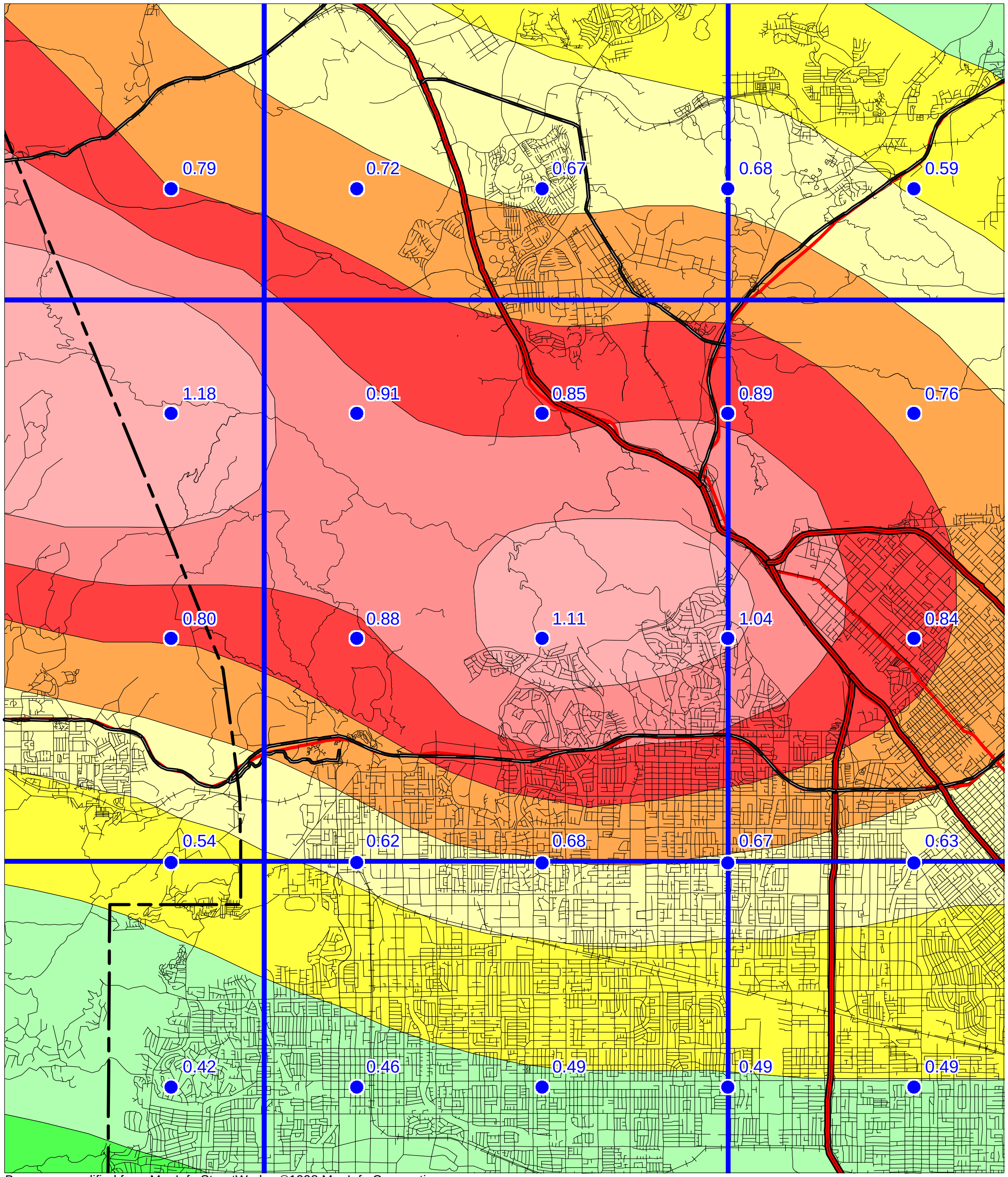
The seismic hazard maps for ground shaking are produced by calculating the hazard at sites separated by about 5 km. Figures 3.1 through 3.3 show the hazard for PGA at 10% probability of exceedance in 50 years assuming the entire map area is firm rock, soft rock, or alluvial site conditions respectively. The sites where the hazard is calculated are represented as dots and ground motion contours as shaded regions. The quadrangle of interest is outlined by bold lines and centered on the map. Portions of the eight adjacent

EL MONTE 7.5 MINUTE QUADRANGLE AND PORTIONS OF ADJACENT QUADRANGLES

10% EXCEEDANCE IN 50 YEARS PEAK GROUND ACCELERATION (g)

1998

FIRM ROCK CONDITIONS



Base map modified from MapInfo StreetWorks ©1998 MapInfo Corporation

0 2.5 5
Kilometers

Department of Conservation
Division of Mines and Geology

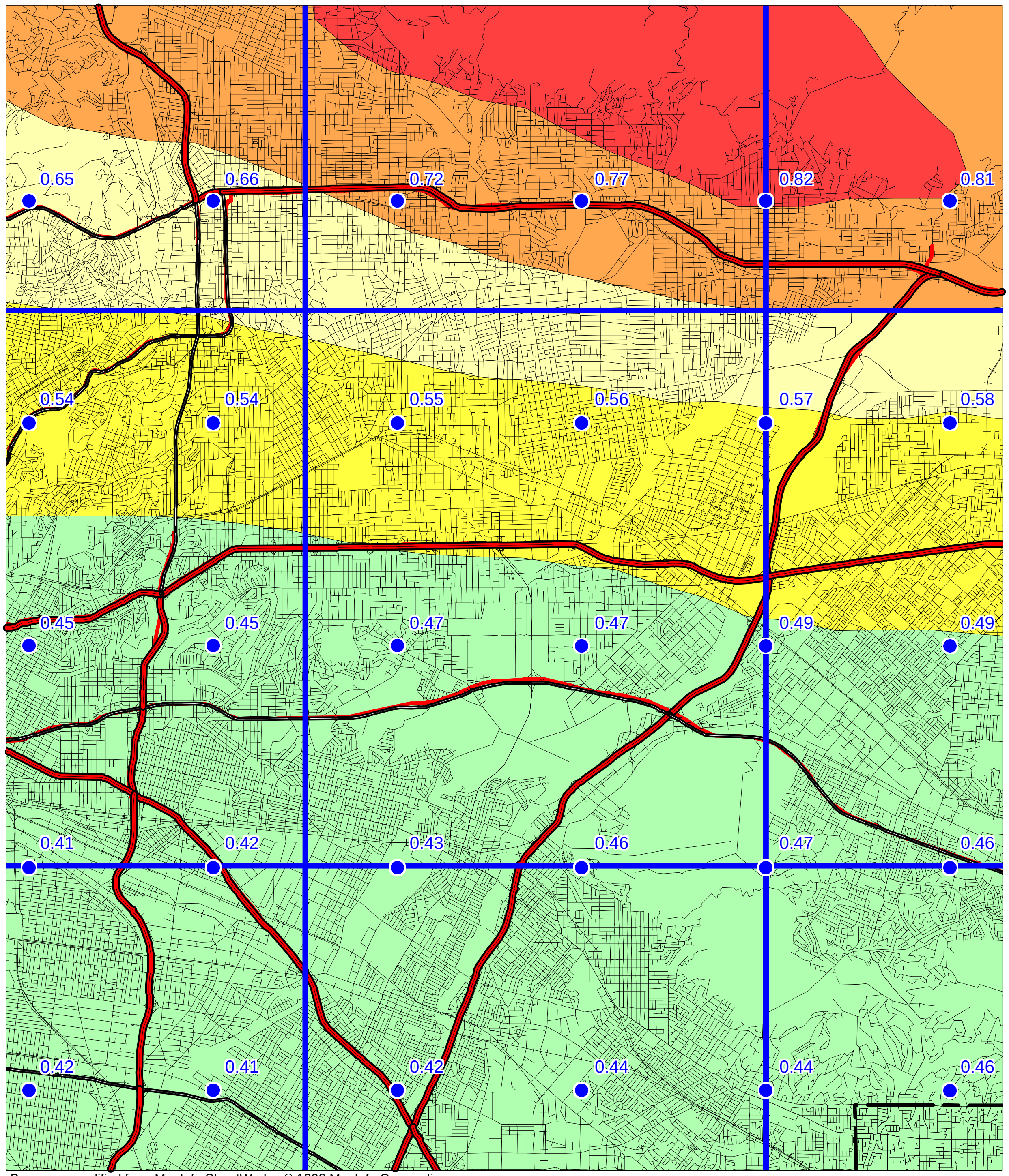
Figure 3.1

EL MONTE 7.5 MINUTE QUADRANGLE AND PORTIONS OF ADJACENT QUADRANGLES

10% EXCEEDANCE IN 50 YEARS PEAK GROUND ACCELERATION (g)

1998

SOFT ROCK CONDITIONS



Base map modified from MapInfo StreetWorks © 1998 MapInfo Corporation

0 2.5 5
Kilometers

Department of Conservation
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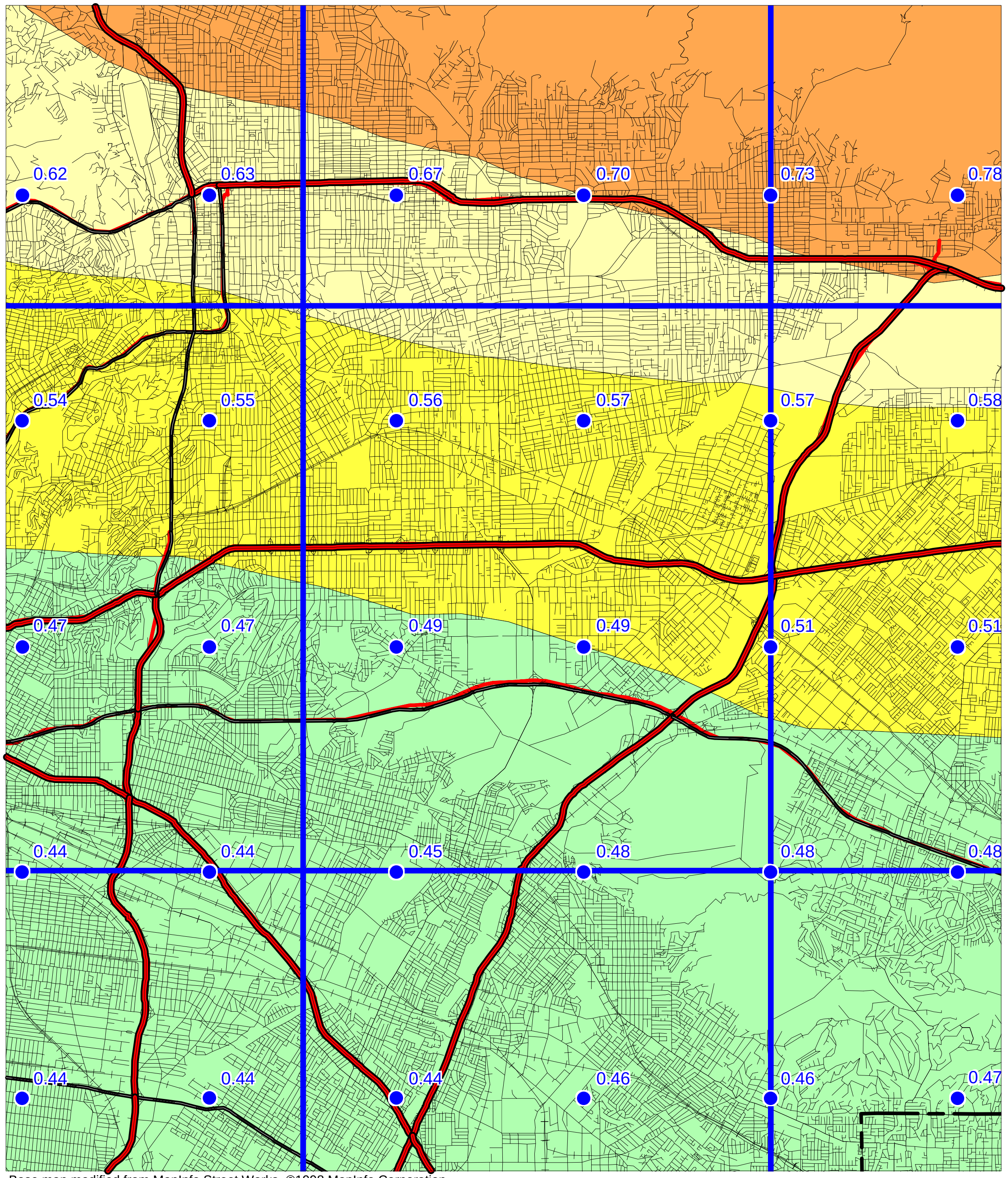
Figure 3.2

EL MONTE 7.5 MINUTE QUADRANGLE AND PORTIONS OF ADJACENT QUADRANGLES

10% EXCEEDANCE IN 50 YEARS PEAK GROUND ACCELERATION (g)

1998

ALLUVIUM CONDITIONS



0 2.5 5
Kilometers

Department of Conservation
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Figure 3.3

quadrangles are also shown so that the trends in the ground motion may be more apparent. We recommend estimating ground motion values by selecting the map that matches the actual site conditions, and interpolating from the calculated values of PGA rather than the contours, since the points are more accurate.

APPLICATIONS FOR LIQUEFACTION AND LANDSLIDE HAZARD ASSESSMENTS

Deaggregation of the seismic hazard identifies the contribution of each of the earthquakes (various magnitudes and distances) in the model to the ground motion hazard for a particular exposure period (see Cramer and Petersen, 1996). The map in Figure 3.4 identifies the magnitude and the distance (value in parentheses) of the earthquake that contributes most to the hazard at 10% probability of exceedance in 50 years on alluvial site conditions (*predominant earthquake*). This information gives a rationale for selecting a seismic record or ground motion level in evaluating ground failure. However, it is important to keep in mind that more than one earthquake may contribute significantly to the hazard at a site, and those events can have markedly different magnitudes and distances. For liquefaction hazard the predominant earthquake magnitude from Figure 3.4 and PGA from Figure 3.3 (alluvium conditions) can be used with the Youd and Idriss (1997) approach to estimate cyclic stress ratio demand. For landslide hazard the predominant earthquake magnitude and distance can be used to select a seismic record that is consistent with the hazard for calculating the Newmark displacement (Wilson and Keefer, 1983). When selecting the predominant earthquake magnitude and distance, it is advisable to consider the range of values in the vicinity of the site and perform the ground failure analysis accordingly. This would yield a range in ground failure hazard from which recommendations appropriate to the specific project can be made. Grid values for predominant earthquake magnitude and distance should **not** be interpolated at the site location, because these parameters are not continuous functions.

USE AND LIMITATIONS

The statewide map of seismic hazard has been developed using regional information and is ***not appropriate for site specific structural design applications***. Use of the ground motion maps prepared at larger scale is limited to estimating earthquake loading conditions for preliminary assessment of ground failure at a specific location. We recommend consideration of site-specific analyses before deciding on the sole use of these maps for several reasons.

1. The seismogenic sources used to generate the peak ground accelerations were digitized from the 1:750,000-scale fault activity map of Jennings (1994). Uncertainties in fault location are estimated to be about 1 to 2 kilometers (Petersen

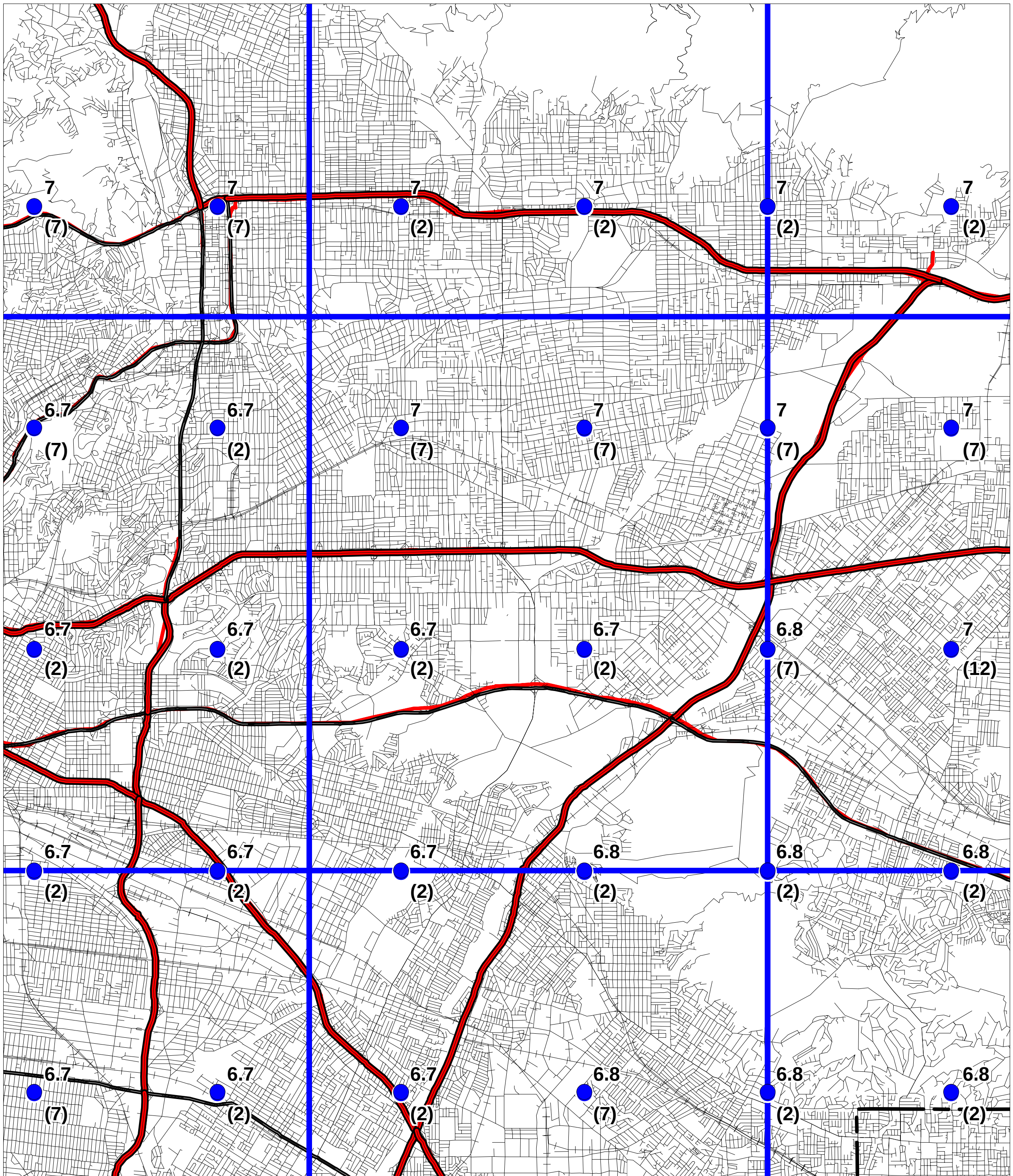
Figure 3.4. El Monte 7.5-Minute Quadrangle and portions of adjacent quadrangles, 10% exceedance in 50 years peak ground acceleration—Predominant earthquake.

EL MONTE 7.5 MINUTE QUADRANGLE AND PORTIONS OF ADJACENT QUADRANGLES

10% EXCEEDANCE IN 50 YEARS PEAK GROUND ACCELERATION

1998

PREDOMINANT EARTHQUAKE
Magnitude (Mw)
(Distance (km))



Base map modified from MapInfo StreetWorks ©1998 MapInfo Corporation

0 2.5 5
Kilometers

Department of Conservation
Division of Mines and Geology

Figure 3.4

1. and others, 1996). Therefore, differences in the location of calculated hazard values may also differ by a similar amount. At a specific location, however, the log-linear attenuation of ground motion with distance renders hazard estimates less sensitive to uncertainties in source location.

2. The hazard was calculated on a grid at sites separated by about 5 km (0.05 degrees). Therefore, the calculated hazard may be located a couple kilometers away from the site. We have provided shaded contours on the maps to indicate regional trends of the hazard model. However, the contours only show regional trends that may not be apparent from points on a single map. Differences of up to 2 km have been observed between contours and individual ground acceleration values. *We recommend that the user interpolate PGA between the grid point values rather than simply using the shaded contours*.

3. Uncertainties in the hazard values have been estimated to be about +/- 50% of the ground motion value at two standard deviations (Cramer and others, 1996).

4. Not all active faults in California are included in this model. For example, faults that do not have documented slip rates are not included in the source model. Scientific research may identify active faults that have not previously been recognized. Therefore, future versions of the hazard model may include other faults and omit faults that are currently considered.

5. A map of the predominant earthquake magnitude and distance is provided from the deaggregation of the probabilistic seismic hazard model. However, it is important to recognize that a site may have more than one earthquake that contributes significantly to the hazard. Therefore, in some cases earthquakes other than the predominant earthquake should also be considered.

Because of its simplicity, it is likely that the SPPV method (California State Mining and Geology Board, 1997) will be widely used to estimate earthquake shaking loading conditions for the evaluation of ground failure hazards. It should be kept in mind that ground motions at a given distance from an earthquake will vary depending on site-specific characteristics such as geology, soil properties, and topography, which may not have been adequately accounted for in the regional hazard analysis. Although this variance is represented to some degree by the recorded ground motions that form the basis of the hazard model used to produce Figures 3.1, 3.2, and 3.3, extreme deviations can occur. More sophisticated methods that take into account other factors that may be present at the site (site amplification, basin effects, near source effects, etc.) should be employed as warranted. The decision to use the SPPV method with ground motions derived from Figures 3.1, 3.2, or 3.3 should be based on careful consideration of the above limitations, the geotechnical and seismological aspects of the project setting, and the “importance” or sensitivity of the proposed building with regard to occupant safety.

REFERENCES

Boore, D.M., Joyner, W.B. and Fumal, T.E., 1997, Empirical near-source attenuation relationships for horizontal and vertical components of peak ground acceleration, peak ground velocity, and pseudo-absolute acceleration response spectra: Seismological Research Letters, v. 68, p. 154-179.

California State Mining and Geology Board, 1997, Guidelines for evaluating and mitigating seismic hazards in California: California Department of Conservation, Division of Mines and Geology, Special Publication 117, 74 p.

Campbell, K.W., 1997, Attenuation relationships for shallow crustal earthquakes based on California strong motion data: Seismological Research Letters, v. 68, p. 180-189.

Cramer, C.H. and Petersen, M.D., 1996, Predominant seismic source distance and magnitude maps for Los Angeles, Orange and Ventura counties, California: Bulletin of the Seismological Society of America, v. 85, no. 5, p. 1645-1649.

Cramer, C.H., Petersen, M.D. and Reichle, M.S., 1996, A Monte Carlo approach in estimating uncertainty for a seismic hazard assessment of Los Angeles, Ventura, and Orange counties, California: Bulletin of the Seismological Society of America, v. 86, p. 1681-1691.

International Conference of Building Officials (ICBO), 1997, Uniform Building Code: v. 2, Structural engineering and installation standards, 492 p.

Jennings, C.W., *compiler*, 1994, Fault activity map of California and adjacent areas: California Department of Conservation, Division of Mines and Geology, California Geologic Data Map Series, map no. 8.

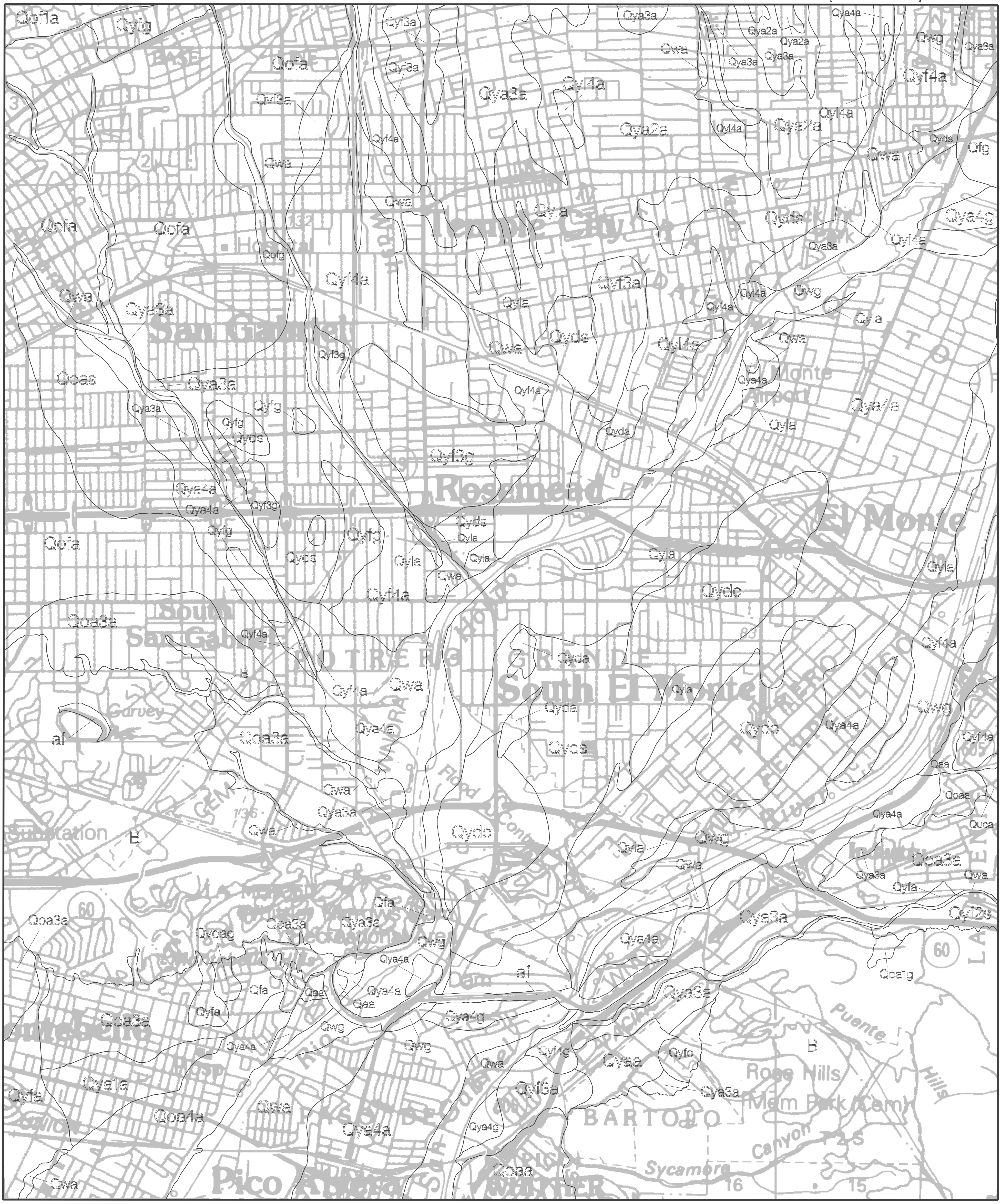
Petersen, M.D., Bryant, W.A., Cramer, C.H., Cao, T., Reichle, M.S., Frankel, A.D., Lienkaemper, J.J., McCrory, P.A. and Schwartz, D.P., 1996, Probabilistic seismic hazard assessment for the State of California: California Department of Conservation, Division of Mines and Geology Open-File Report 96-08; also U.S. Geological Survey Open-File Report 96-706, 66 pp.

Sadigh, K., Chang, C.-Y., Egan, J.A., Makdisi, F. and Youngs, R.R., 1997, SEA96- A new predictive relation for earthquake ground motions in extensional tectonic regimes: Seismological Research Letters, v. 68, p. 190-198.

Wilson, R.C. and Keefer, D.K., 1983, Dynamic analysis of a slope failure from the 1979 Coyote Lake, California, Earthquake: Bulletin of the Seismological Society of America, v. 73, p. 863-877.

Youd, T.L. and Idriss I.M., 1997, Proceedings of the NCEER workshop on evaluation of liquefaction resistance of soils: Technical Report NCEER-97-0022, 40 p.

Youngs, R.R., Chiou, S.-J., Silva, W.J. and Humphrey, J.R., 1997, Stochastic point-source modeling of ground motions in the Cascadia Region: Seismological Research Letters, v. 68, p. 74-85.



Base map enlarged from U.S.G.S. 30 x 60–minute series

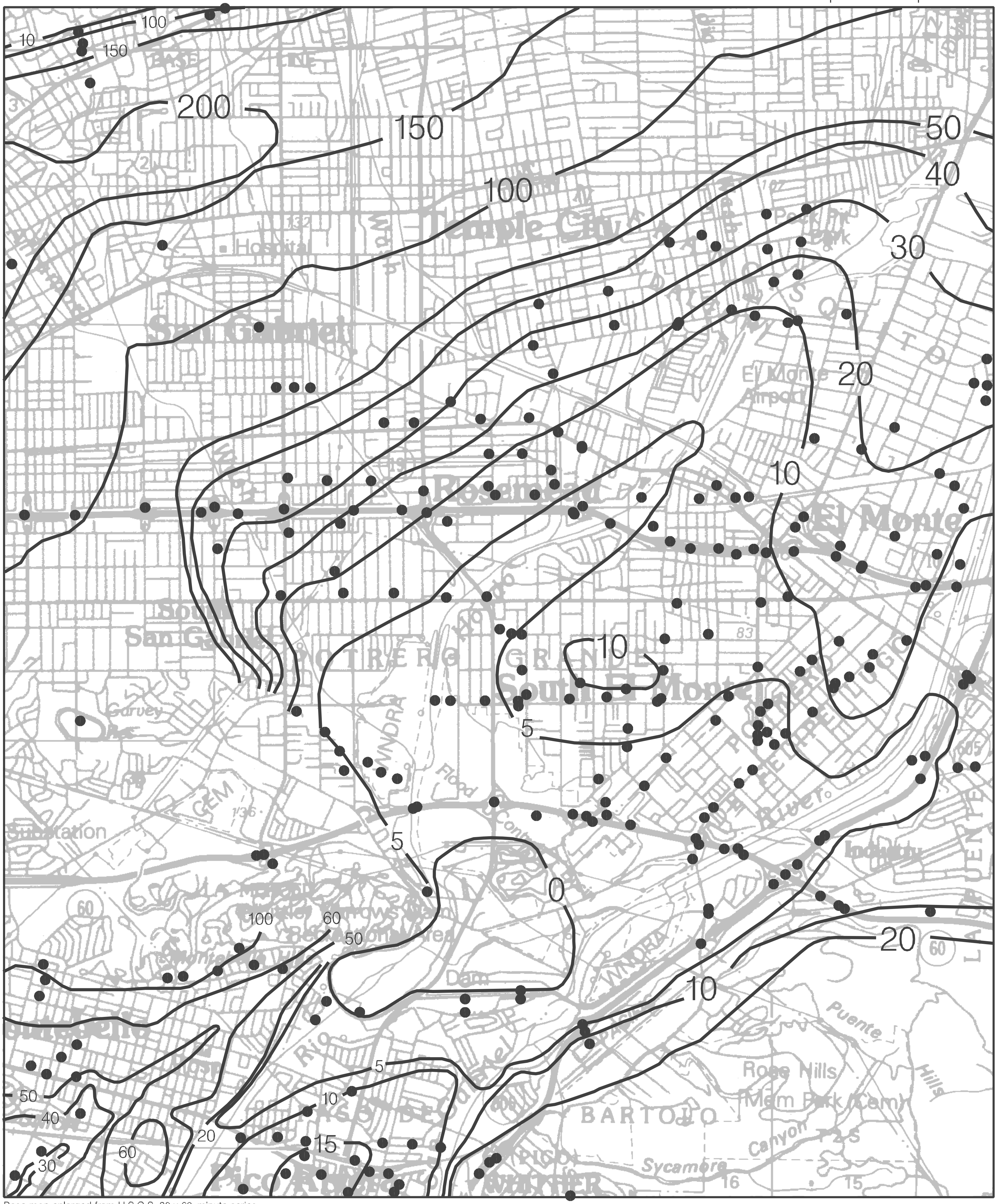
Plate 1.1 Quaternary Geologic Map of the El Monte Quadrangle.

See Geologic Conditions section in report for descriptions of the units.

B = Pre–Quaternary bedrock.

ONE MILE

SCALE



Base map enlarged from U.S.G.S. 30 x 60–minute series

Plate 1.2 Historically Highest Ground Water Contours and Borehole Log Data Locations, El Monte Quadrangle.

● Borehole Site

30 Depth to ground water in feet

ONE MILE

SCALE

Base map enlarged from U.S.G.S. 30 x 60–minute series

Plate 2.1 Landslide inventory, Shear Test Sample Locations, and Areas of Significant Grading, El Monte Quadrangle.

shear test sample location landslide areas of significant grading

ONE MILE

SCALE